AN INTERNATIONAL PARTNERSHIP IN SEABED METHANE HYDRATES R&D

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Abstract–Natural gas (methane) hydrates represent an enormous hydrocarbon resource that could potentially satisfy the energy needs of the world for centuries. The primary known repositories of methane hydrates are arctic permafrost zones and undersea basins on the continental margins. Major R&D programs to investigate methane hydrates have been initiated in Japan, India, and recently in the U.S. The University of Hawaii and the Naval Research Laboratory are pursuing an international partnership on seabed methane hydrates with scientists and engineers from the U.S., Japan, Korea, and Norway. This paper summarizes the plans for this activity. As conceived, the partnership will offer extensive cross-discipline technical resources and expertise that will be applied to determine methane hydrate resource distribution and availability; develop viable recovery technologies; establish safety procedures for offshore commercial and military installations in hydrate sediment zones; and evaluate the impact of methane hydrates on climatic change.

1. BACKGROUND

According to recent assessments, natural gas hydrates (hereinafter referred to interchangeably as methane hydrates–since methane is the most abundant hydrate-forming component of natural gas) represent an enormous untapped hydrocarbon resource. Methane hydrates are crystalline solids comprising water molecules linked by hydrogen bonds in a tight polyhedral cage structure. Guest molecules, including various hydrocarbons found in natural gas mixtures, reside in the interstices of this lattice. The ratio of water molecules to guest molecules in methane hydrates is estimated to be 6.2 with small variations (Uchida *et al.*, 2000). At these proportions, a cubic meter of hydrate yields about 160 standard cubic meters of methane and 0.9 m^3 of liquid water on decomposition (Max & Cruickshank, 1999).

Methane hydrates form when natural gas components and water come in contact at elevated pressures and low temperatures. For example, at 0°C, a hydrate phase exists at pressures above 26 atmospheres in mixtures of water and pure methane. At 25°C, this minimum pressure increases to about 440 atmospheres (Sloan, 1990). Ethane and propane, which are often present at significant levels in natural gas, form hydrates at lower pressures than methane below about 5°C and 17°C, respectively.

The primary known repositories of methane hydrates are arctic permafrost zones and undersea basins on the continental margins where temperatures and pressures are conducive to hydrate formation and stability (Kvenvolden, 1988; Makogan, 1988; Gornitz and Fung, 1994). Sediment layers in deep ocean basins also may contain large deposits of hydrates. Estimates of the total volume of hydrocarbons locked in hydrate deposits worldwide range widely from about 10^5 trillion standard cubic feet (TCF) to 2.7 x 10^8 TCF (i.e., 2.8 x 10^{15} to 7.6 x 10^{17} cubic meters). Even at the lower end of this range, this resource could potentially satisfy the energy needs of the world for centuries, provided that practicable recovery techniques can be devised.

During the first half of the 20th century, hydrate blockage of natural gas pipelines posed a serious problem and research was undertaken to develop solutions (Sloan, 1990). Once solutions were identified and implemented, interest waned. Naturally-occurring methane hydrates for many decades remained largely a curiosity, with limited practical significance.

Several issues have sparked renewed interest in methane hydrates. While offering tremendous opportunities as a future primary energy resource, marine hydrate deposits also represent an immediate and formidable nuisance to offshore oil and gas operations (Max & Cruickshank, 1999; Cruickshank & Masutani, 1999). This problem has become more critical as these commercial activities move into increasingly deeper waters. From a defense perspective, there is a need to characterize the geoacoustic properties of hydrate sediments and to assess their potential as an *in situ* offshore energy source, since this information is relevant to Naval operations. Finally, methane hydrates may exercise a profound effect on global climate if carbon sequestered in these solids is released into the environment by commercial exploitation of the fuel or through destabilization and outgassing induced by ocean warming (MacDonald, 1990).

2. INTERNATIONAL PARTNERING

The commercial, environmental, and military implications of methane hydrates have led to new national research initiatives in Japan and India and the development of a Methane Hydrates Program Plan by the Department of Energy and other U.S. Government agencies (Office of Fossil Energy, 1998 & 1999). This plan constitutes the basis for the Methane Research Development Act of 1999 that was introduced as U.S. House Bill HR 1753 and U.S. Senate Bill S330.

2.1 National R&D Programs

The Government of Japan established the first large-scale national exploratory hydrate research program in 1995. In 1998, the Japan National Oil Corporation sponsored drilling tests of known hydrate deposits in the McKenzie Delta in Canada (Dallimore *et al.*, 1999). A second five year R&D plan was authorized last year which will be overseen by the New Energy & Industrial Technology Development Organization (NEDO), a government-industry partnership whose operating budget largely is provided by the Ministry of International Trade and Industry. The goal of the Japanese program is to commence commercial production of natural gas from undersea hydrates by 2010.

In 1996, India became the second nation to establish a hydrate research program. The Oil Industry Development Board of India earmarked $56 million for an effort to be carried out under the auspices of the Gas Authority of India, Ltd. Industry cooperation is paramount in this initiative and low energy prices have reduced incentives and hampered progress.

In addition to these R&D activities in Japan and India, the U.S., Canada, and the European Union have begun assessments of deep water hydrocarbons, including methane hydrates.

2.2 U.S. R&D Program

In April 2000, the U.S. Senate authorized an appropriation of $47.5 million over five years to the Department of Energy (DOE) for methane hydrates R&D. The House of Representatives passed this bill earlier and it has been sent to the President, who is expected to sign it. Until fiscal year 2000, U.S. federal funds for research in this area were limited; for example, between 1982 and 1992, the DOE coordinated a multi-agency methane hydrates program that had an annual budget of less than $1 million.

The current U.S. Methane Hydrates Program Plan devised by DOE identifies four primary R&D goals: (1) determination of the locations and extent of the worldwide methane hydrate resource; (2) development of recovery technologies for commercial production of methane by 2015; (3) assessment of the role of methane hydrates in the global carbon cycle and climatic change; and (4) eliminating or minimizing risks to offshore commercial operations associated with sediment hydrate mass movement or outgassing events.

2.3 Rationale for International Cooperation

Although national interests must be protected in certain areas of development, it is proposed that international collaboration is a logical and effective means to pursue the basic science and engineering of methane hydrates.

As an energy resource, there is evidence that substantial deposits of methane hydrates exist in coastal regions, within national Exclusive Economic Zones (EEZs). This suggests that disputes over recovery rights should be limited and resolvable and that individual nations stand to benefit directly from timely exploitation of their offshore hydrate reserves. It is therefore in the general best interests to pool resources and work cooperatively to obtain a comprehensive understanding of the global methane hydrate resource and to develop practicable recovery processes and safety procedures.

Fuel production from methane hydrates will profoundly restructure the world economy. Furthermore, global climate may be affected as carbon sequestered in these hydrates is released into the environment as a result of this resource exploitation or inadvertently through destabilization and outgassing induced by ocean warming. The international community will share the associated burdens and benefits. This common interest supports an international approach to address key research issues.

2.4 Overview

Since the beginning of 1999, the Hawaii Natural Energy Institute (HNEI) of the UH and the Naval Research Laboratory have been working together to organize an international research partnership that will collaborate on studies of methane hydrate science and technology. To date, several groups from the U.S., Japan, Korea, and Norway have agreed to participate in this partnership. Cooperative agreements and memoranda of understanding are being negotiated with the Hokkaido National Industrial Research Institute of the Agency of Industrial Science & Technology of the Government of Japan, the Korea Research Institute of Chemical Technology, and Inha University (Korea). Commitments have been obtained from researchers at the Norwegian Institute for Water Research (NIVA) and the University of Bergen (Norway). Discussions are ongoing with other National Laboratories and universities in Japan and Korea, and organizations in India, Canada, and Russia.

The international research partnership is being organized to provide extensive cross-discipline technical resources and expertise that will be applied to determine methane hydrate resource distribution and availability; develop viable recovery technologies; establish safety procedures for offshore commercial and military installations in hydrate sediment zones; and evaluate the impact of methane hydrates on climatic change. A detailed research program involving field, laboratory, and modeling studies is being synthesized that will efficiently leverage the intellectual and financial capabilities of the different participants. Proposed topics of study include: field sampling of hydrates, sediments, pore waters, and the water column to investigate geochemical and biological factors that control methane hydrate formation and stability (Coffin *et al.*, 2000); high-resolution, deep-tow multi-channel seismology to characterize the hydrate stability zone; seafloor acoustic imagery to identify and quantify gas fluxes through sediment; numerical modeling of fluid transport in complex media; *in situ* and laboratory studies of properties, kinetics, and themodynamics of natural gas hydrates and sediment; *in situ* and laboratory studies of deep natural gas releases into the water column; and development of diagnostics for field and laboratory studies of methane hydrates.

The participants will pool resources in order to operate effectively and efficiently. A reasonable level of redundancy and independence will be retained in order to provide the capacity for verification of research results. By virtue of its international make-up, the group will have extensive access to hydrate sites in the participants' national waters and will be able to utilize local facilities to stage field studies. This approach offers clear cost and technical advantages.

It is anticipated that participants will initially need to secure support from within their countries. Later, as the benefits of international cooperative research on methane hydrates emerge, major projects that are jointly funded by a number of organizations from stakeholder nations may become feasible. The model for such projects is the ongoing CO_2 ocean sequestration field experiment that is being supported by the Governments of Japan, the U.S., Norway, and Canada (Masutani & Nihous, 1998).

HNEI and NRL are both participating in the CO_2 ocean sequestration field experiment. This project has demonstrated the viability of international research partnering and has addressed many structural issues relevant to the proposed methane hydrates initiative such as funding mechanisms and intellectual property.

3. SUMMARY

Natural gas hydrates represent an enormous hydrocarbon resource that could potentially satisfy the energy needs of the world for centuries. The primary known repositories of methane hydrates are arctic permafrost zones and undersea basins on the continental margins. Major R&D programs to investigate methane hydrates have been initiated in Japan, India, and recently in the U.S.

While national interests needs be protected in certain areas of development, it is proposed that international collaboration is a logical and effective means to pursue the basic science and engineering of methane hydrates.

The core of such an international research partnership has been established through a joint effort between HNEI and NRL. This partnership offers extensive cross-discipline technical resources and expertise that will be applied to determine methane hydrate resource distribution and availability; develop viable recovery technologies; establish safety procedures for offshore commercial and military installations in hydrate sediment zones; and evaluate the impact of methane hydrates on climatic change. Scientists and engineers from government agencies, universities, and the private sectors in the U.S., Korea, Japan, and Norway have agreed to collaborate through the partnership, and a research program involving both field, laboratory, and modeling studies is being synthesized that will efficiently leverage the capabilities of the different participants.

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